



Simulation of Aircraft Arrest Gear with MSC.ADAMS

Feasibility Study

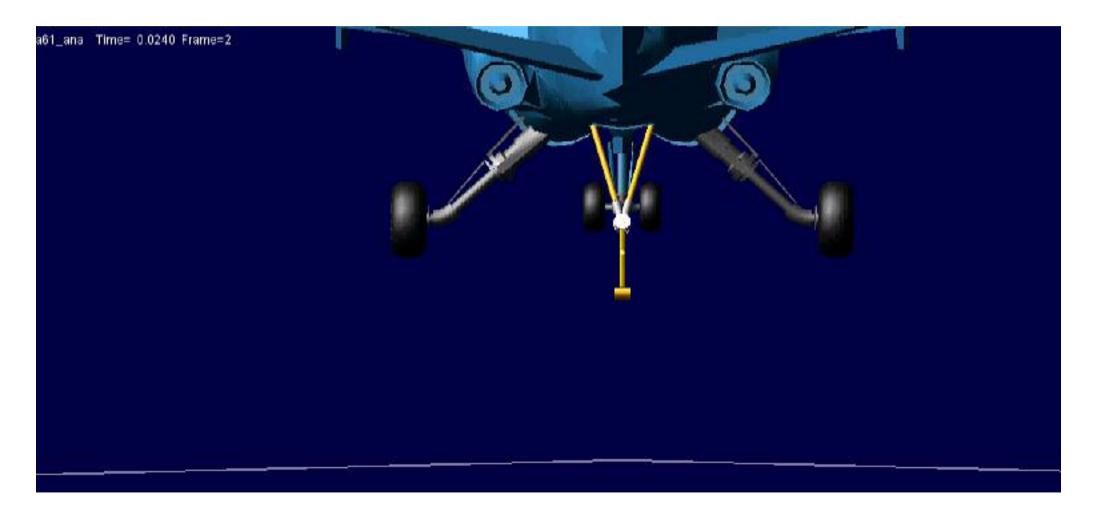
SayField International & MSC.Software





Problem Overview

(MSC.Software demo model)





Project Goals

SAY FIELD

- 1. Global model of arresting gear
 - Geometry of complete gear
 - No (or limited) lateral cable dynamics
 - Accurate description of MEC dynamics
- 2. Detailed model of cross-deck pendant
 - Lateral cable dynamics
 - Describe kink wave after plane impact
- 3. Combination of models 1. and 2.
 - Technological challenge





Project Challenges

- Cable dynamics:
 - Discrete cable model: lateral + axial dynamics
 - Spring-based cable model: axial dynamics only
 - How to combine Discrete and Spring-based?
- Arrest gear (or MEC) model:
 - Method applied: Translate Matlab/Simulink to MSC.ADAMS syntax
- Model parameters:
 - Cable data measured and implemented





Agenda

- Cable modelling
- Cable Toolkit
- Modelling methods
- Cable Data Measurement
- Simulation Results
- Conclusions
- Further research





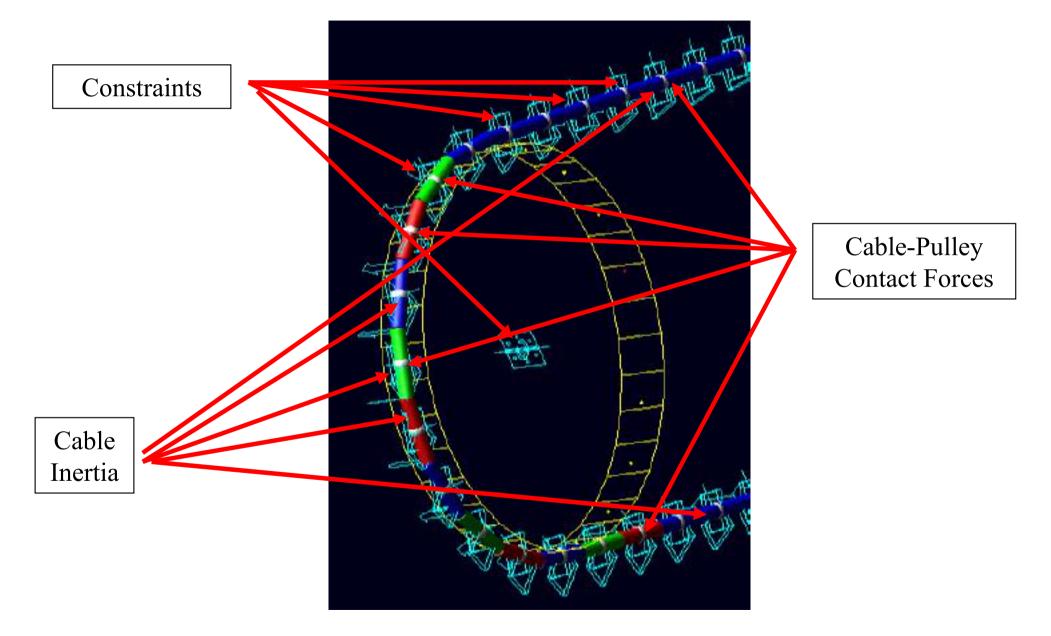
Cable model methods

- Discretized vs. Spring-based cable models
 - Discretized:
 - Cable is divided in *n* rigid parts (n > 100)
 - Pulleys (*p*) are modelled as rotating parts
 - Contact cable-pulley through impact/ gforce
 - Nr. of contacts = n * p
 - Spring-based:
 - Cable mass doesnot move
 - Cable mass accounted for in pulley rotation
 - Cable is essentially a massless spring-force model
 - Pulley rotations are passed through cable forces





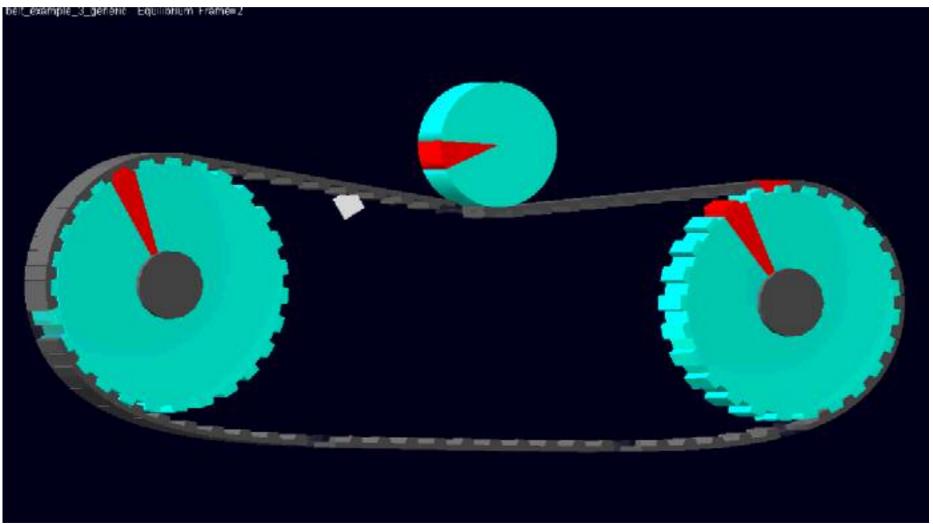
Discretized cable: parts & constraints & contacts







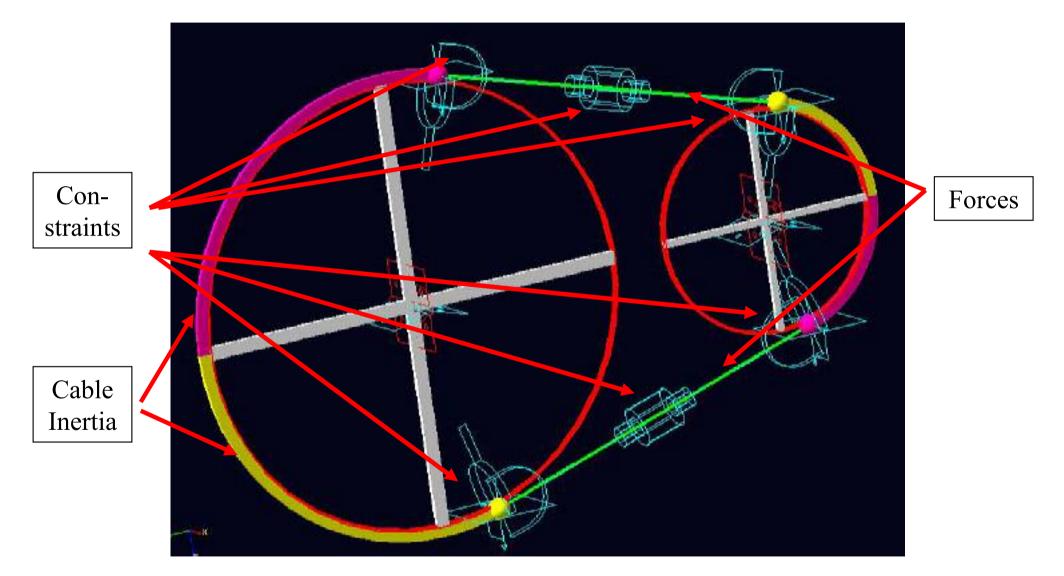
Sample discretized method (from ADAMS/Engine)







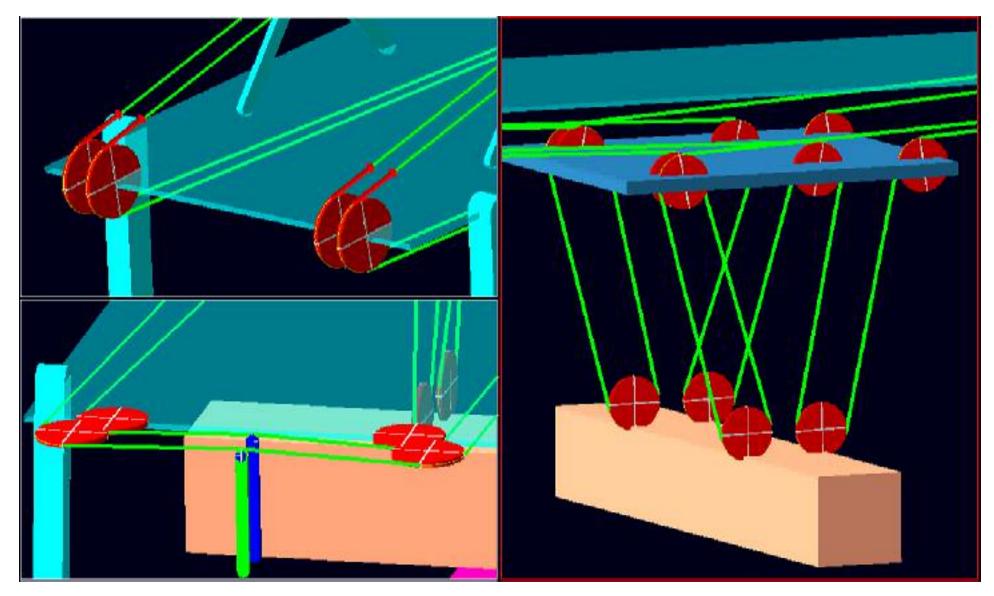
Spring-based cable: pulleys & forces & constraints







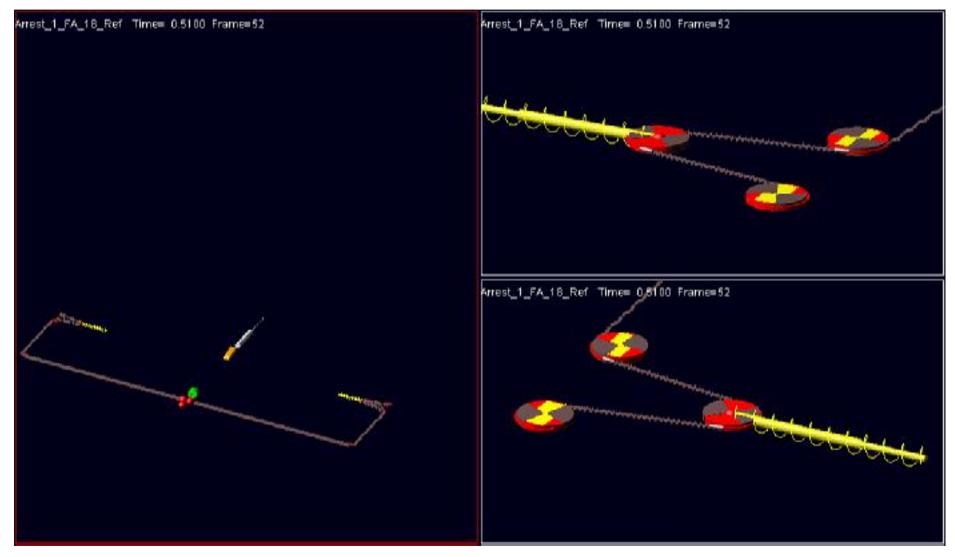
Sample Spring-based method (container crane dynamics)







Sample Spring-based method (arrest gear model 1)







Cable & Belts Toolkit

- Customised modelling tools
- Macros and User Dialogs
- Parametrised Cable models
- Data Structures for Cables & Pulleys
- ASCII Parameter Dbase
- Spring-based & Discrete Cables





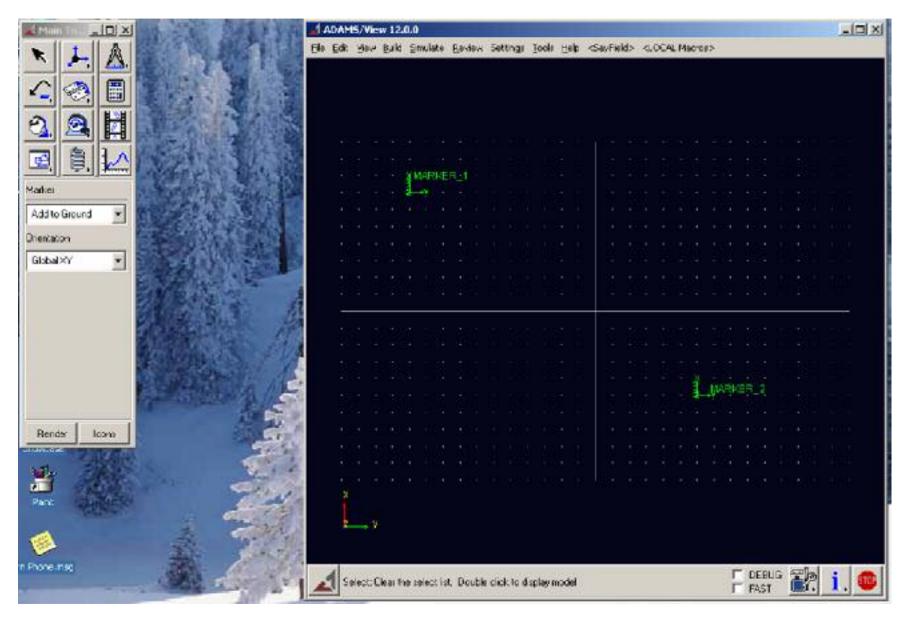
Start modelling session

	ADAMS/View 12.0.0	LOX
× 9. A.	Ele Edit Yew Build Simulate Berden Settings Tools Help (SavField> (LOCAL Macros>	
second second second is the second seco		
		ł
2 <u>2</u> H		
	1 141 STURIES 28 HERBER 18 18 STURIES 28 1	
View Econol	The second side as a second of the second	
X 9 2		
C b Q		
	🗧 – a cala a cala di	
Increment 30.0	· · · · · · · · · · · · · · · · · · ·	
		64 (0.0108516) (0.010 (0.010))
	🔚 – KI XUMU NA WU N UN NI N 🛛 🖉 WU KUK NA K	E LONGE DEL
Grid Depth	👔 🔄 1951 1972 1973 1973 1973 1973 1973 1973 1973 1973	
Render Icons	🧖 – Real Real and Real and a contract of the Real Real Real Real Real Real Real Rea	
7.7.7.7	📲 - 101 20101 201 201 0 201 201 2 - 10 201 2 201 2 201 2	
Pare distante		
There are a set of the		
r Protecting		
		EBUG 👔 i. 🚳
	L.	





Define Pulley Reference Markers







Define Pulley Data Structure & Pulleys

		ADAMS/View 12.0.0	A DESCRIPTION OF TAXABLE PARTY.		_ ID! X
x LA	Pulley		wex Settings Look Heb <sayfield< th=""><th>> KLOCAL Macr</th><th>962</th></sayfield<>	> KLOCAL Macr	962
	Data			🛃 Pulley Oak	a Hinneger 📃 🔲 🔟
	Force			Model	Cable_Model
<u>a</u> 🛛	Part			Name	Cable_Model PLDAT_1
second included whether	Chair				Fixet Tangent
🖻 🔋 📈	Contact			Pulley Type	Ficat_Tangent
Marker	Data	STATE OF			[11.20] I
Add to Ground	UDE Loader		المترجي ومعادية	Mass	
Crientation	Initialise Loope	STATE IN		inetia (Izz)	[1. Qkg·mm**2])
	Update Loops			Badke	(0.8 (m))
GlobalXY -	Update	Pulley Manager	× · · · · ·	Width	[1.0e-2 in]]
	Unparametrize	Model Cable_Model		Nr. of Teeth	0
	Crosse Build File	Name Cable_ModeLFulley_2	CONTRACTOR OF THE		[10mm]
	System trils	Pulley Data Cable_ModeLPLDAT_1		Teeth Radias	
	Initial Speed	Release Cable_ModeLground NARKER_2		Base Redui	[III]
	Measure	Feady		Fies Torque	[D.C1 N·m]]
	Hun			Res Omega	[[0.01]]
Render Loone		Set Doleto Minimizo Freeze Dose			[1.0e-3 (kg))
STRAW		100		Angle	[0.1 (d)]
1				Color	bers redico.
Part States				ACL_Data/De	faultoules
-				Concession of Street, or other	
S 🖗 🖉	35	A REAL PROPERTY.		Sel Del	ete Read White Core
in Phone.msg	14				F DEBUG 🐒
	- Contraction of the local division of the l	<u>A</u>			FAST 📲 🗸





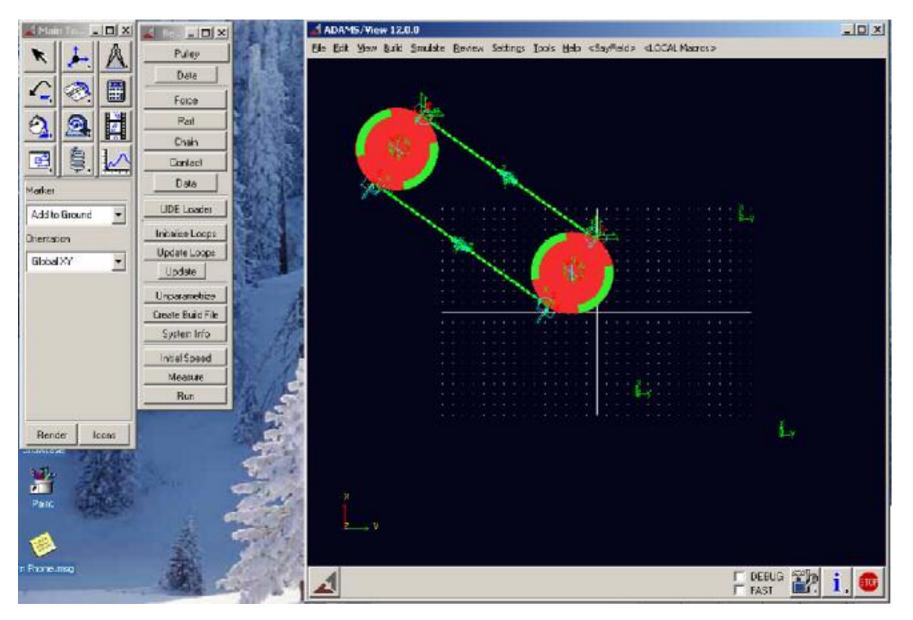
Define Cable Force Data Structure & Cables

		* * 10	ADAM5/View 12.0.0	🖞 Bolt Data Ma		
K J. A	Puley	B	le Edit View Build Simulate Beview Settings Jools Help <sayfield></sayfield>	Model	.Cable_Model	-
400	Data			Nane	.Cable_ModelBelt_Data_1	
	Force	E.		Density	(7801.0)×g/m*38	
3 2 1	Pat			Height	[1.0E-002 m[]	
e \$. 14	Chain Contact			Width	[1.0E-002im]]	
Markes	Date	1.5		Younge Modulus	(2.07E+011(N/m**2))	
Add to Ground 👻	UDE Loader	100		Axial Factor	0.5	
Directation	Initialise Locos			And Damp Rate	(1.0E-002(sec))	
	Update Loops			Bend Factor	1.0E-003	
Gibbal XY 🗾	Update	Contraction of the second		Bend Damp Rate	[7.0E-002[sec]]	
	Unparamehice	4		Strain Flamp Up	1.0E-005	
	Dreate Build File System Info	A		Redial & Te	ooth Contact Parameters	
	Initial Speed	11	Belt Force Manager	Toolh Pitch	[1.0E-002[m]]	
	Measure	A.	Model Cable_Model	Stiffness	[2.0E+005(N/m])	
	Run	15	Name Cable_Mode/Bet_2	Demp Rele	(1.0E-002(s))	
	1	2	Bell Data Cable_Model Bel_Data_1	Force Expon	1.9	
Render Icons	24	14	Belt_Puley .Cable_ModelFuley_2	Penellation	(0.1)mm]	
	8	the an	J Belt_Pulley . Cable_ModelPulley_1	Factor Coefficient	0.1	
Part:		a.	Show Vectors Velocity	Slp Speed	(1.0E-003)m/s))	
ASACC	1	to and		Init. Force	[0.0N]	
1	1 2	1 star	Set Dekte Close	Golar	.colos:.GREEN	
n Phone Jriso		State .	.4	ACL_Dala/Delay	a Est	
	- And And And		<u>43</u>	Set Delete	Read Write Close	-





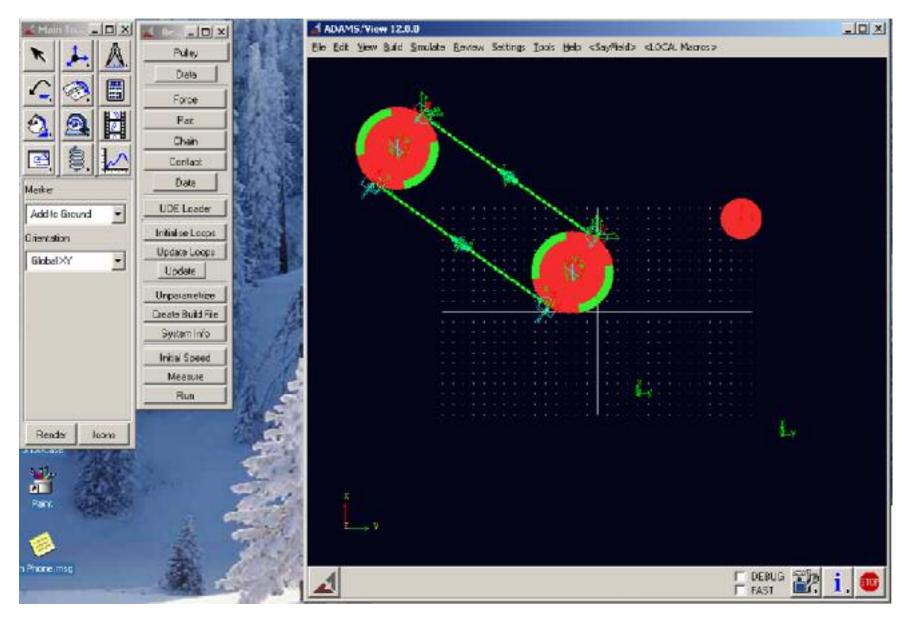
Define Markers for Discrete Cable







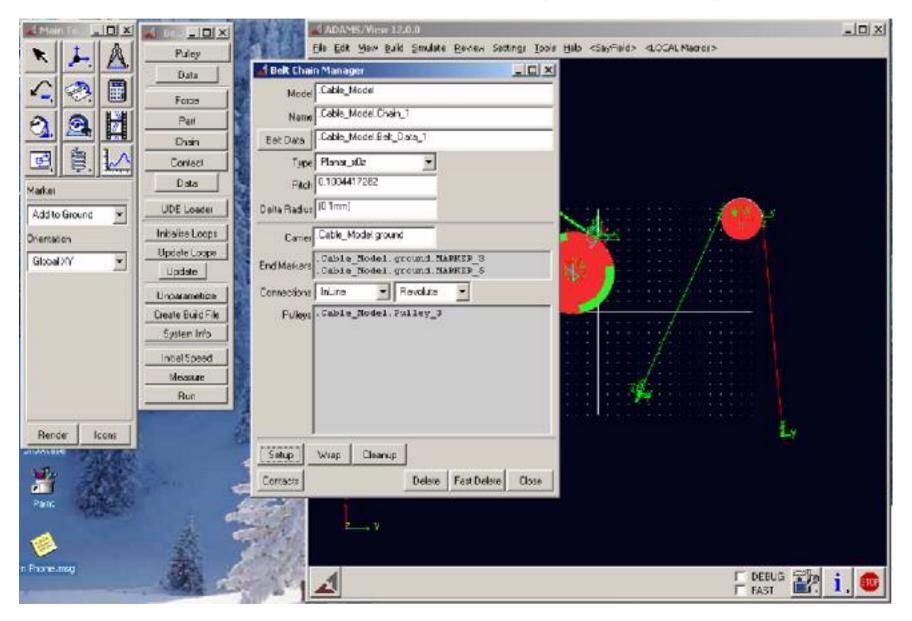
Define and Minimize Pulley







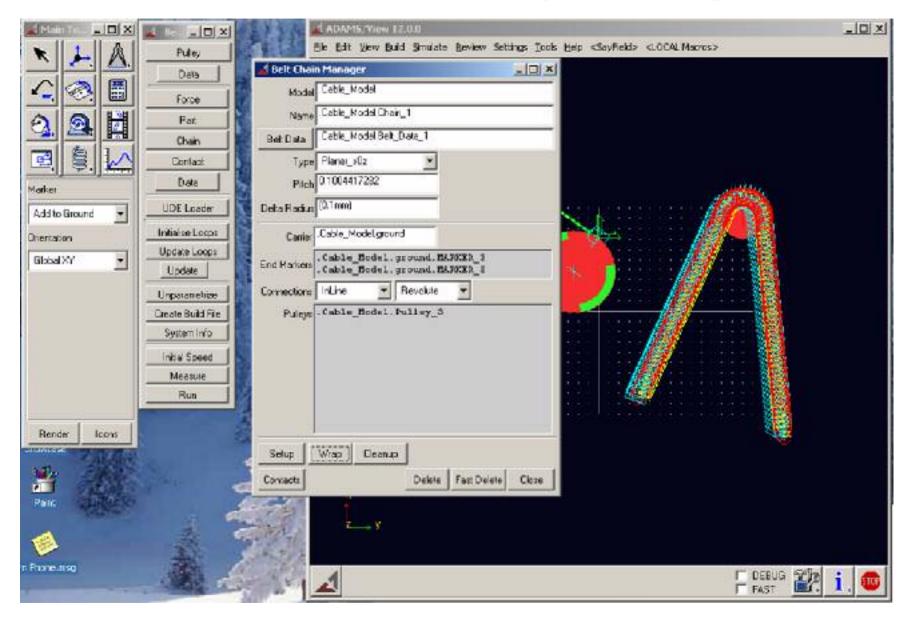
use the Belt Chain Manager and Setup the Chain







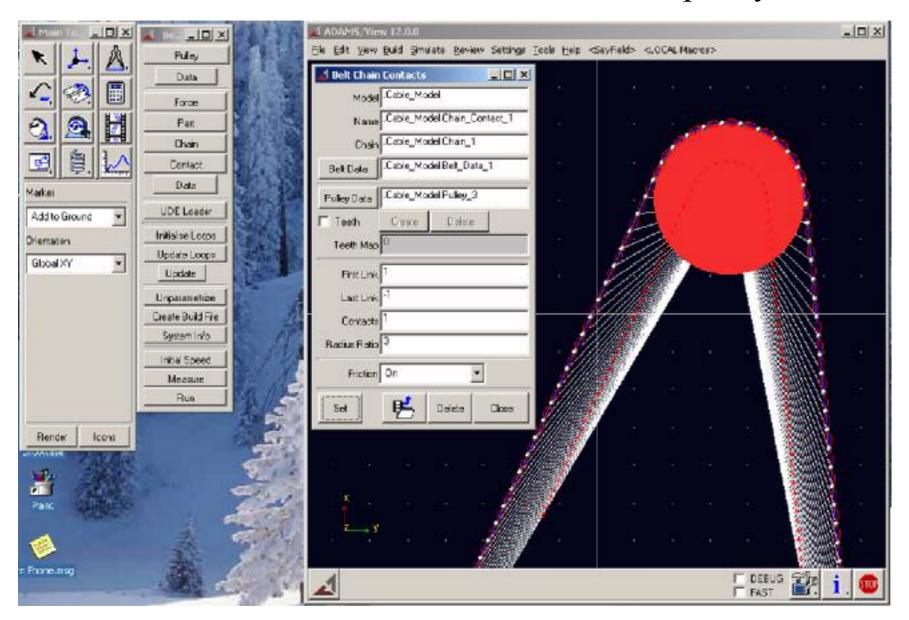
use the Belt Chain Manager and Wrap the Chain







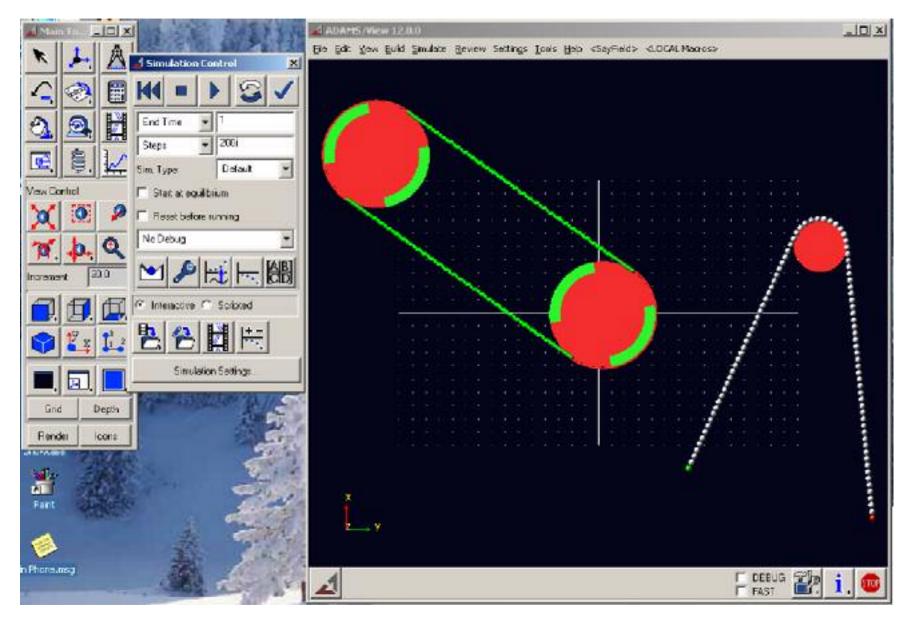
Create contacts between chain and pulley







Run Simulations







Different models defined

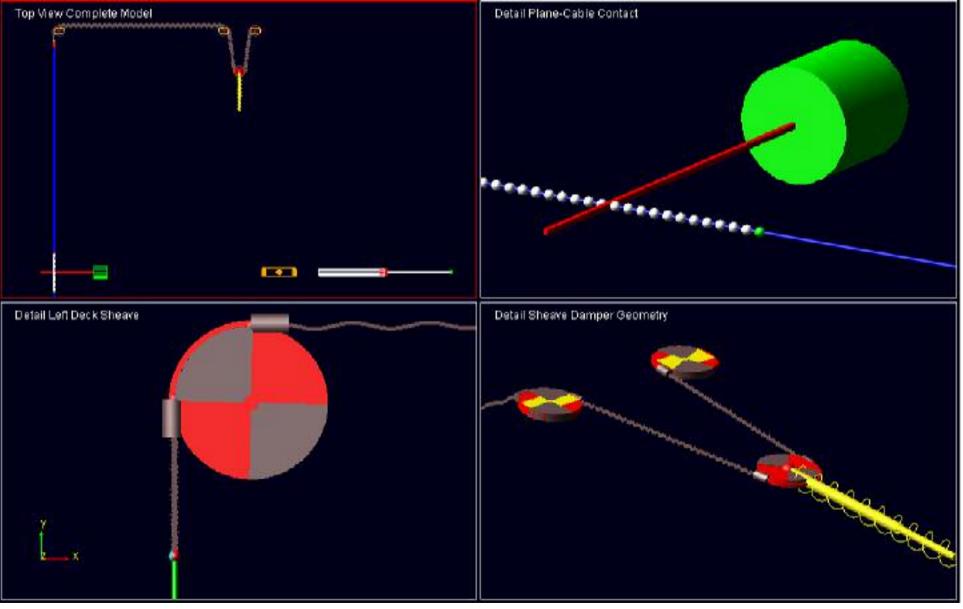
Model

Description

- 1. Spring-based cables, non-linear sheave dampers
- 2. Discrete cross-deck, simple sheave dampers
- 3. Discrete cross-deck, non-linear sheave dampers
- 4. Discrete cables only, simple sheave dampers
- 5. *Hybrid* cables, non-linear sheave dampers

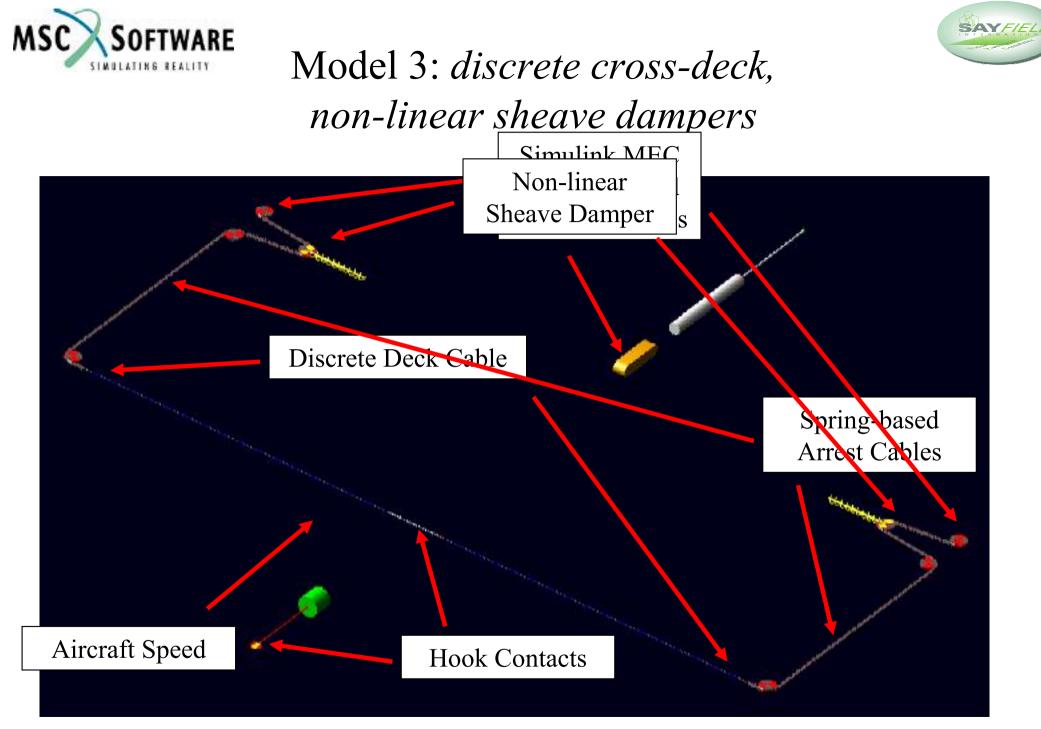


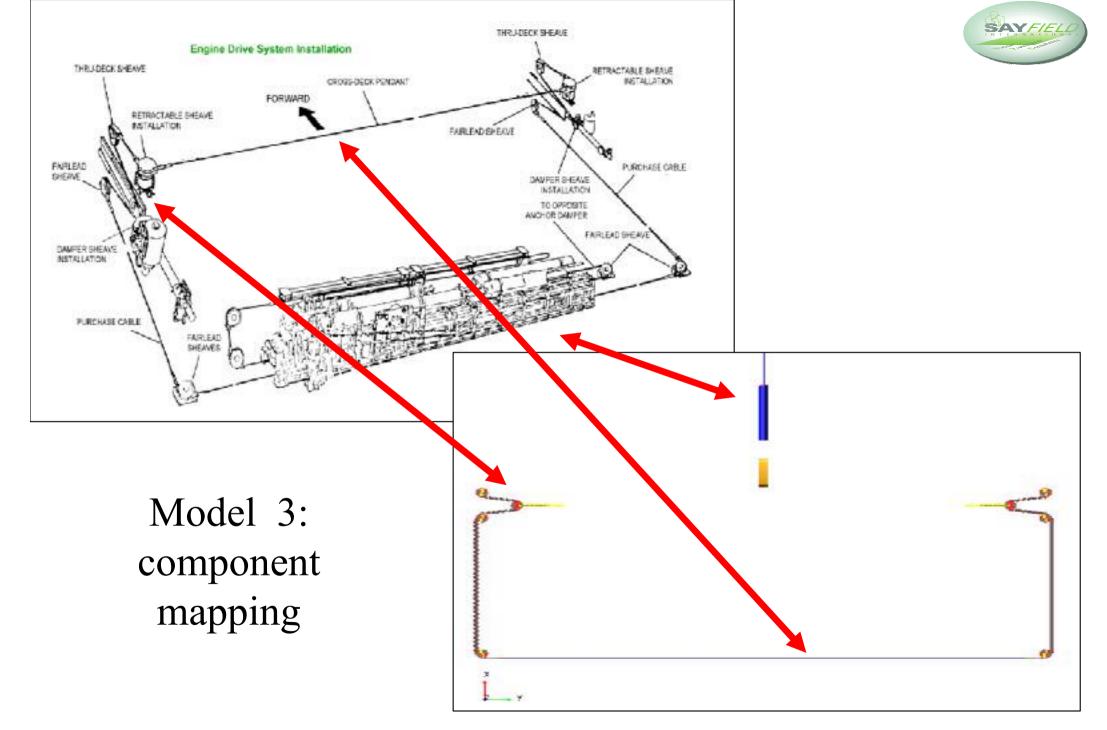
Model Components



Arrest Gear Simulation

SAYFIEL

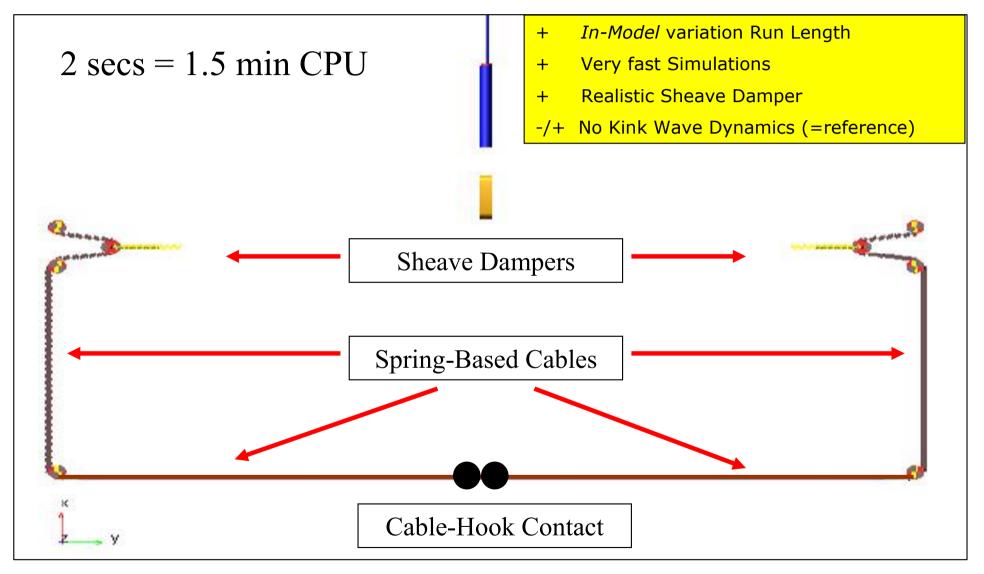








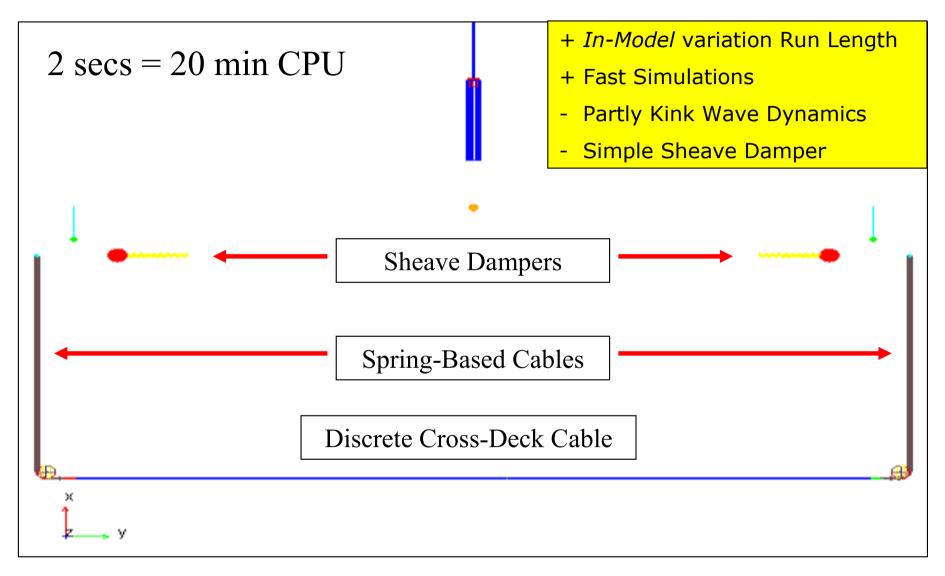
1: Spring-based cables, Non-Linear Sheave Dampers







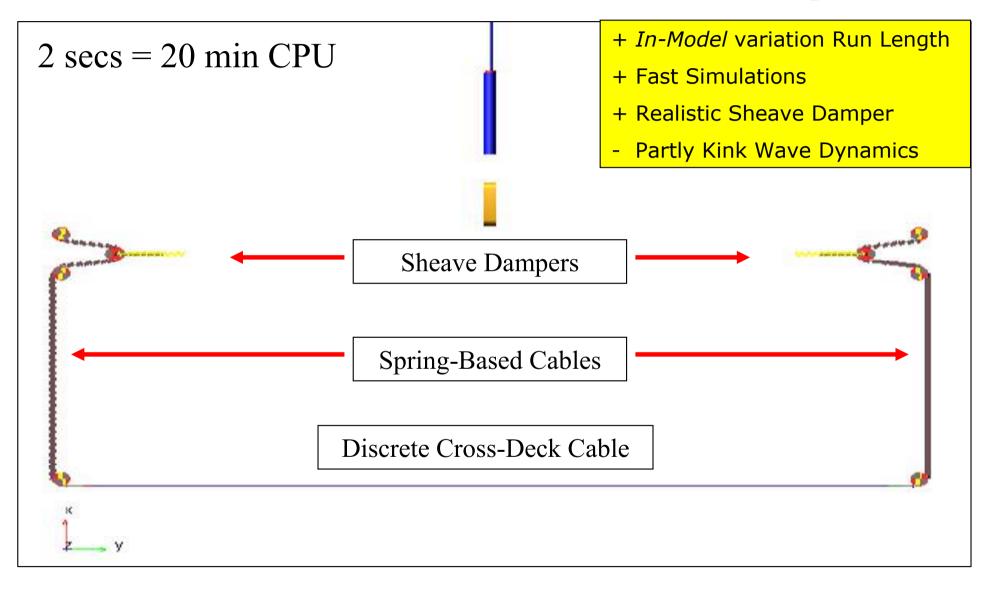
2: Discrete Cross-deck, Simple Sheave Dampers







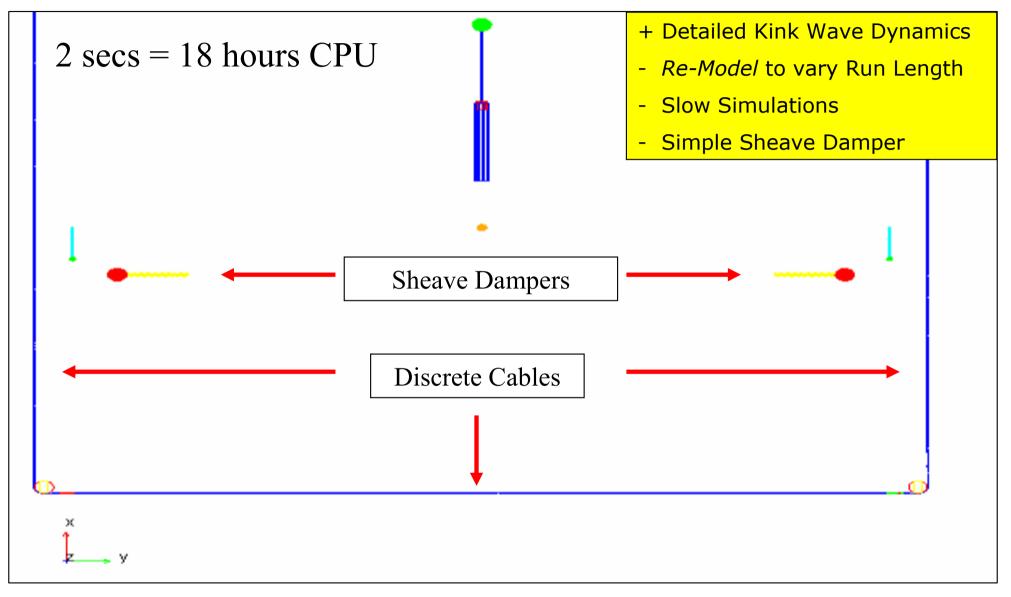
3: Discrete Cross-deck, Non-Linear Sheave Dampers







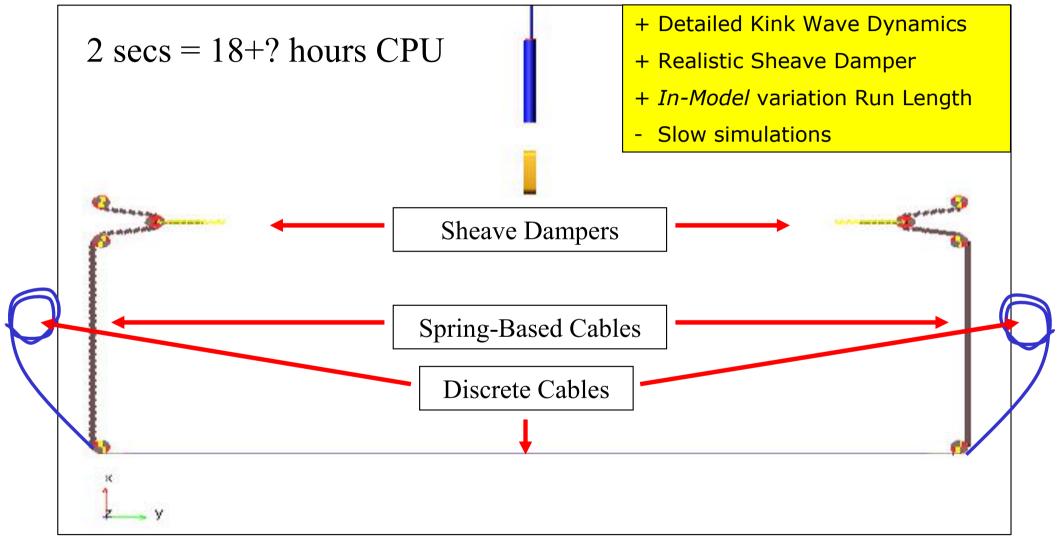
4: Discrete Cable Only, Simple Sheave Dampers







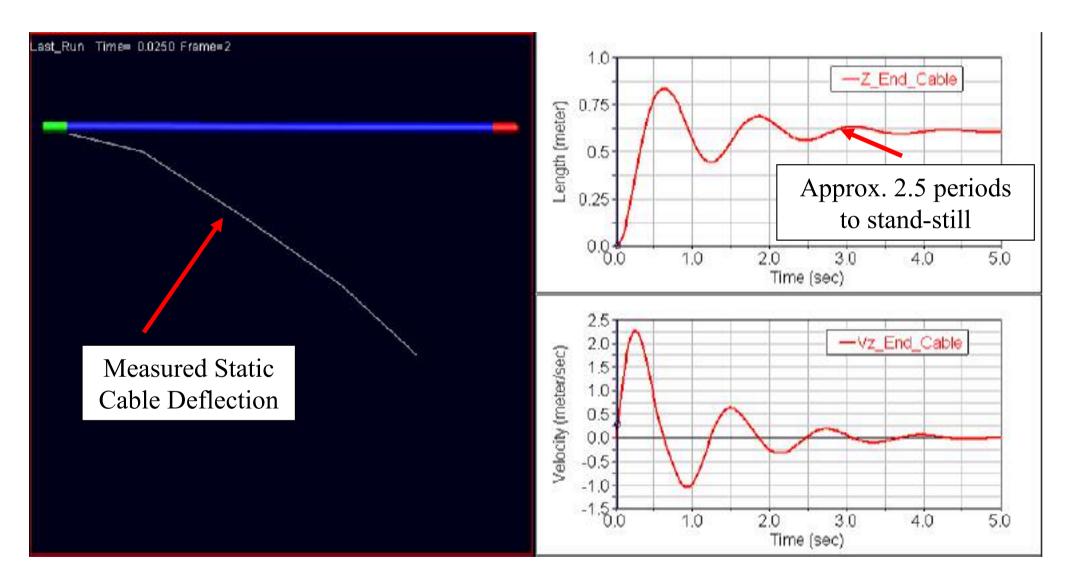
5: *Hybrid* Cable, Non-Linear Sheave Dampers **To Be Defined !!!**







Cable Data Measurements





→ ASCII Cable Data File

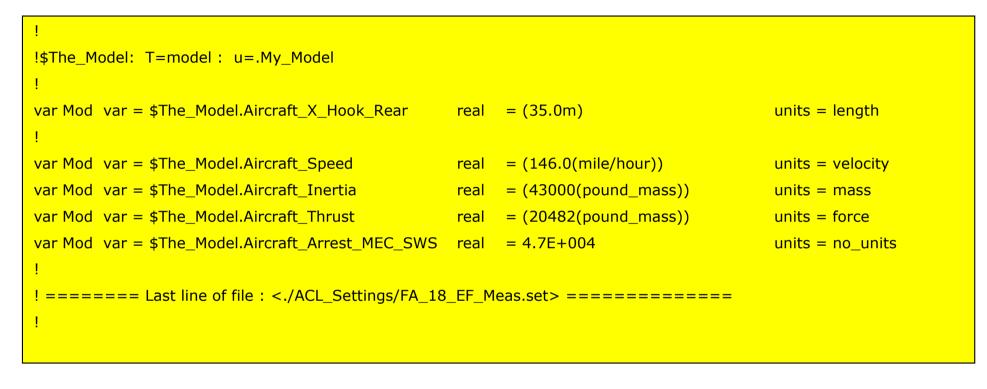


!\$The_Model: T=model: u=.MEC_Springs				
!\$Data_Name: T=Belt_Data : u=.MEC_Springs.Cable_Data				
var mod var = \$Data_Name.Density	real = (7801.0(kg/m**3))			
var mod var = \$Data_Name.Youngs	real = (2.07E+011(N/m**2))			
var mod var = \$Data_Name.Axial_Factor	real = 0.5			
var mod var = \$Data_Name.Bend_Factor	real = 5.2E-007			
var mod var = \$Data_Name.Axial_Damp_Rate	real = (1.0E-002(sec))			
var mod var = \$Data_Name.Bend_Damp_Rate	real = (0.1(sec))			
var mod var = \$Data_Name.Ramp_up	real = 1.0E-005			
var mod var = \$Data_Name.Tooth_Pitch	real = (1.0E-002(m))			
var mod var = \$Data_Name.Cont_Stiff	real = (5.0E+005(N/mm))			
var mod var = \$Data_Name.Cont_Damp_Rate	real = (1.0E-005(s))			
var mod var = \$Data_Name.Cont_Expon	real = 2.9			
var mod var = \$Data_Name.Cont_Pene	real = (0.1(mm))			
var mod var = \$Data_Name.Frict_Coeff	real = 0.2			
var mod var = \$Data_Name.V_Slip	real = (0.2(m/s))			
var mod var = \$Data_Name.Height	real = (30(mm))			
var mod var = \$Data_Name.Width	real = (30(mm))			
var mod var = \$Data_Name.Frc_Init	real = (1.55E+004N)			
! ======= Last line of file : <./ACL_Data/Arrest_Cable.belt> ====================================				





Example: ASCII Aircraft Data File



- + All aircraft data stored in single ASCII File
- + Usable across models and across users
- + Supports good management of simulation data





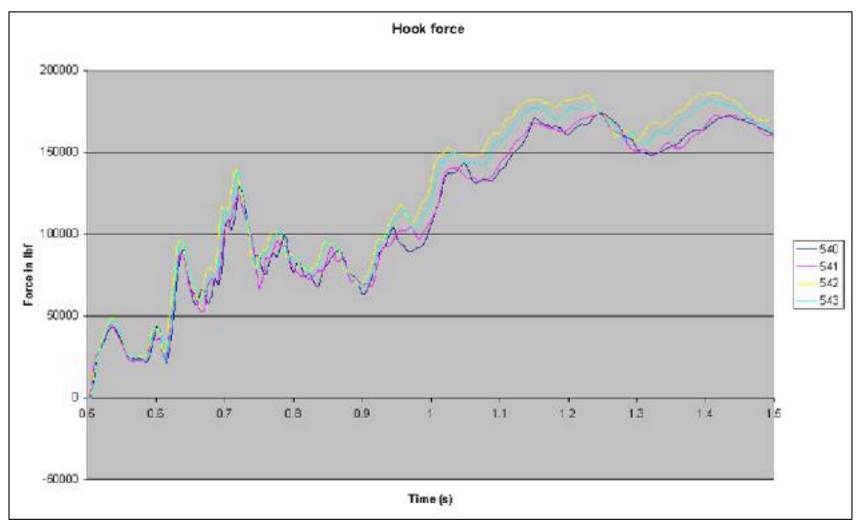
Simulation Results

- Parameter studies:
 - Axial cable stiffness (DOF of discrete cable)
 - Transversal stiffness/damping of cables
 - Cable discretization pitch
 - Appropriate cable-to-pulley contact data
 - Aircraft settings applied





Measurement Results

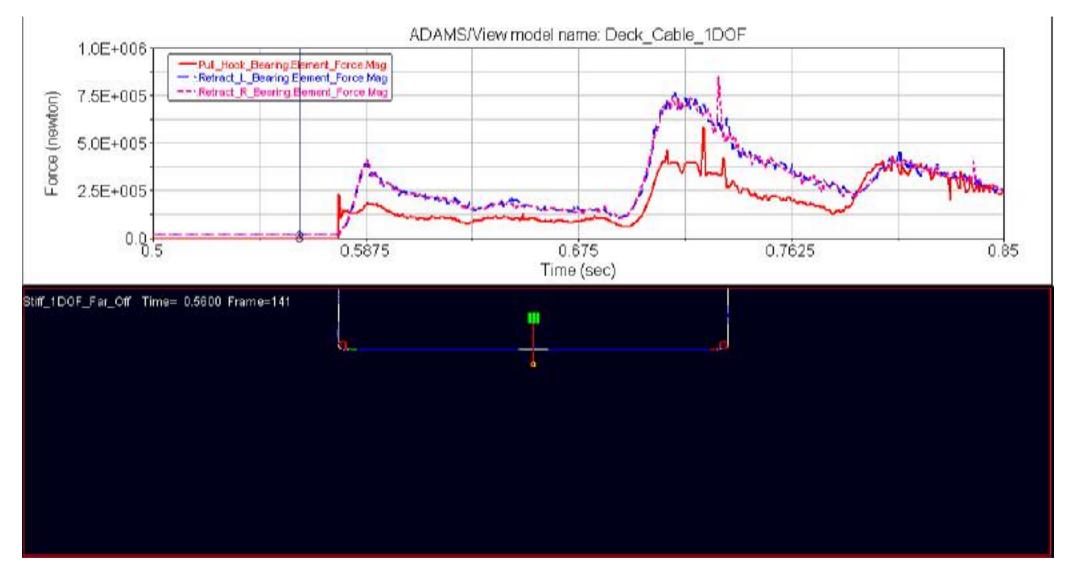


 \rightarrow Excellent repeatability in measurements



Simulation Movies



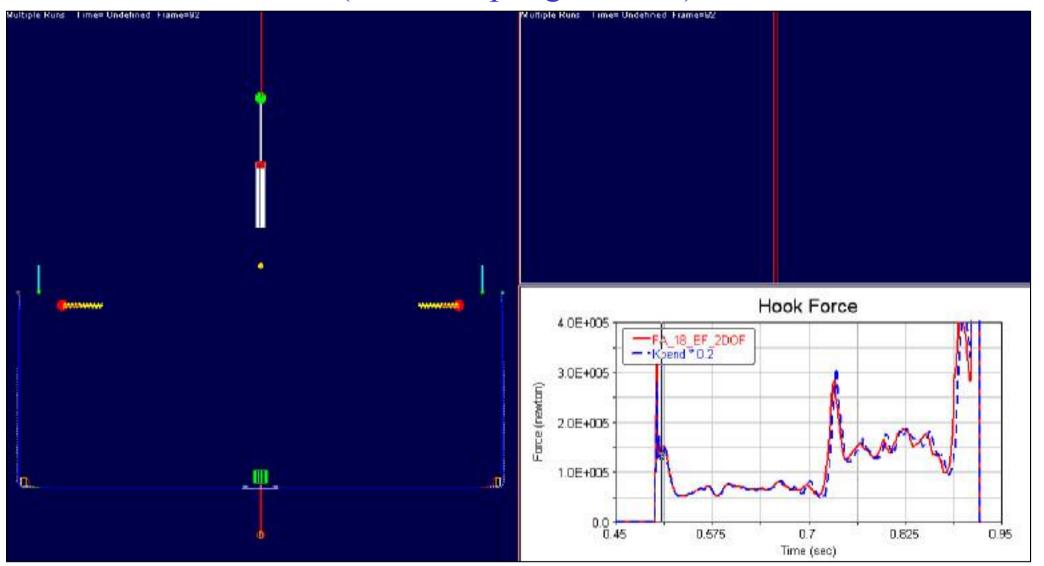


Model 4: kink wave and impacts clearly visible



Initial version of Model 4 (linear coupling to MEC)

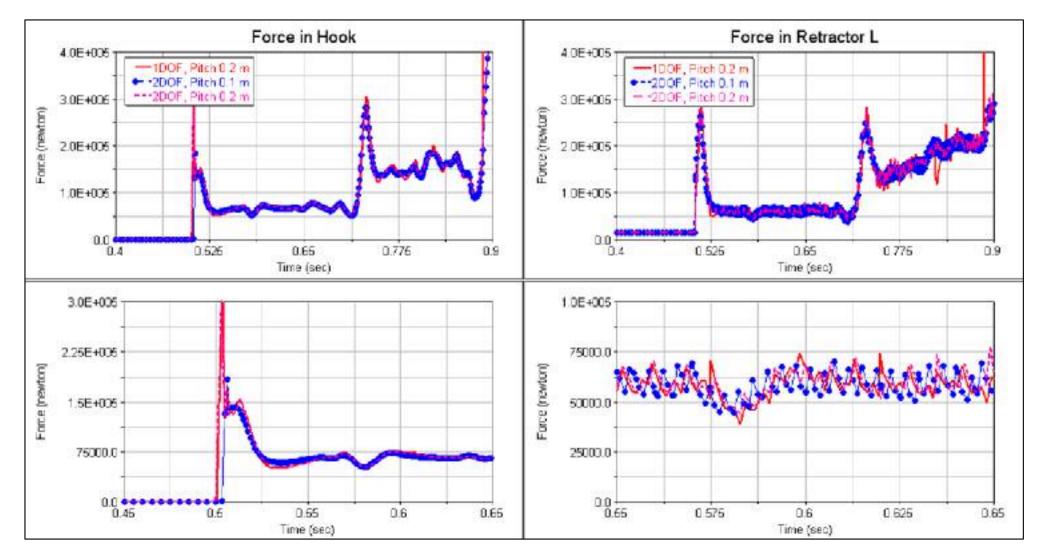




Model 4: Small effect of axial & bend stiffness on hook load



Simulation Results



 \rightarrow Minimal effect of cable Pitch & axial deformation

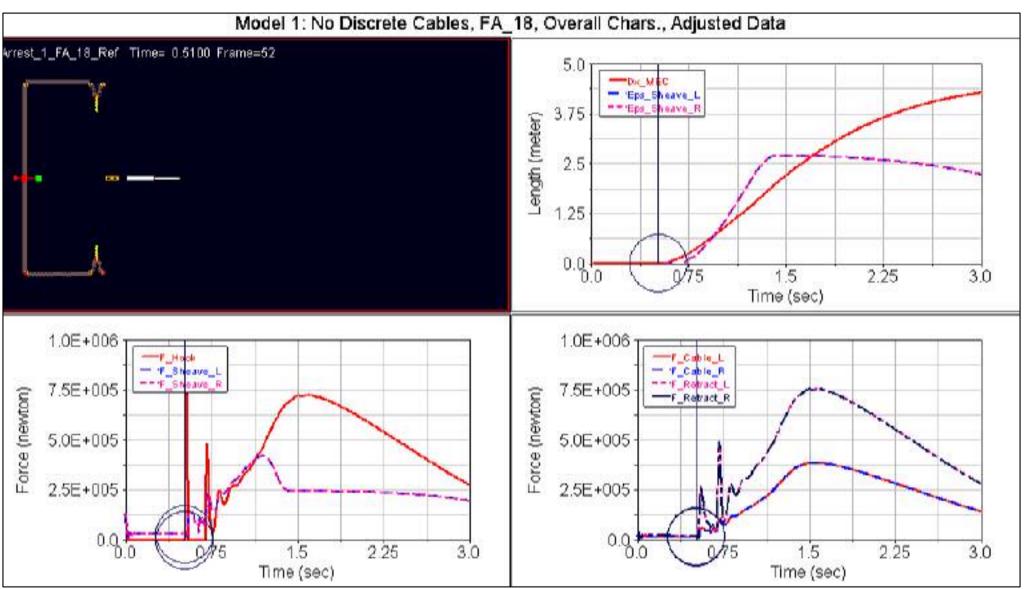
Arrest Gear Simulation

SAY FIELD



Model 1: overall behaviour



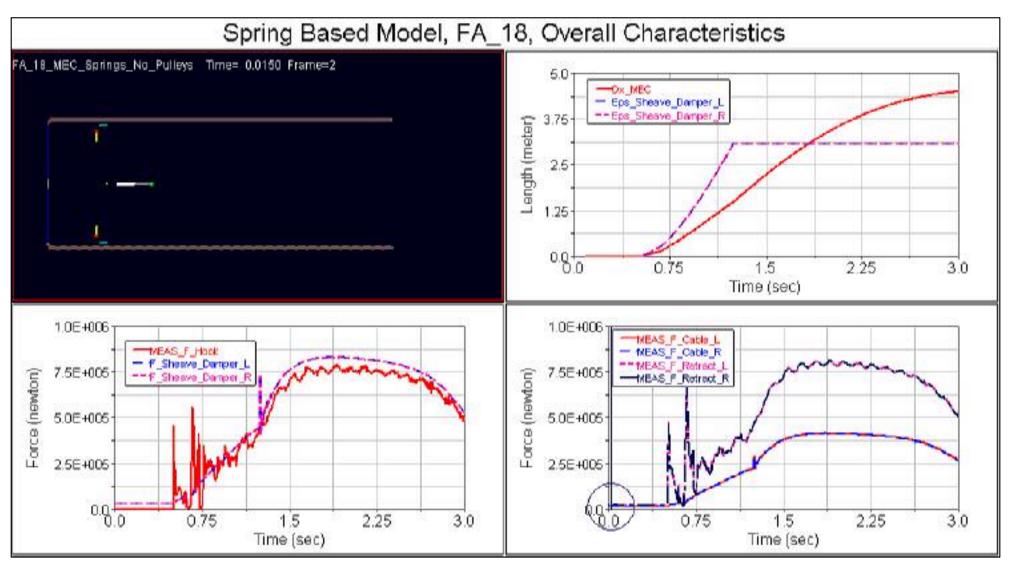


 \rightarrow Model 1: fast representation of overall behaviour



Model 2: overall behaviour



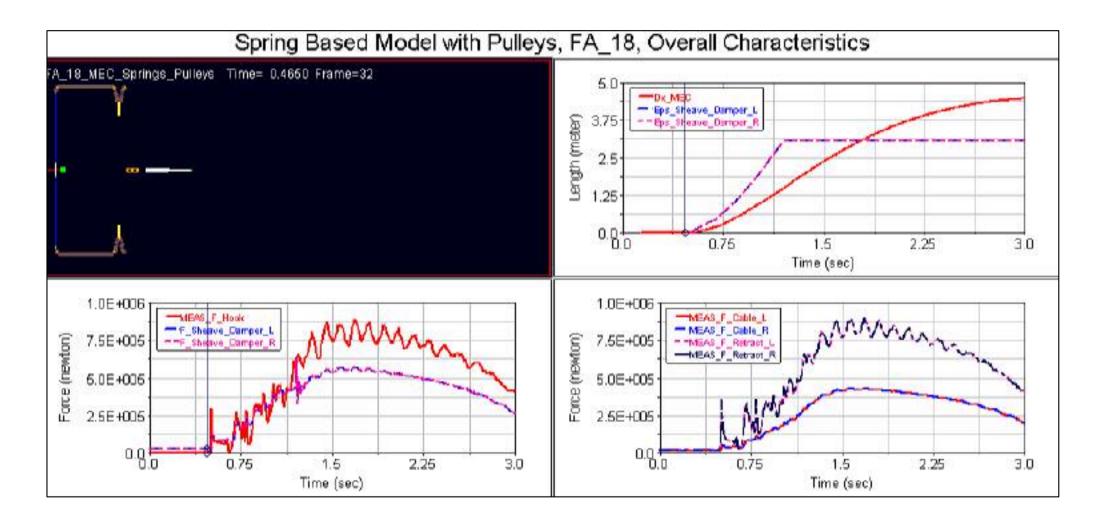


 \rightarrow Model 2: deviations from sheave damper linearity





Model 3: overall behaviour

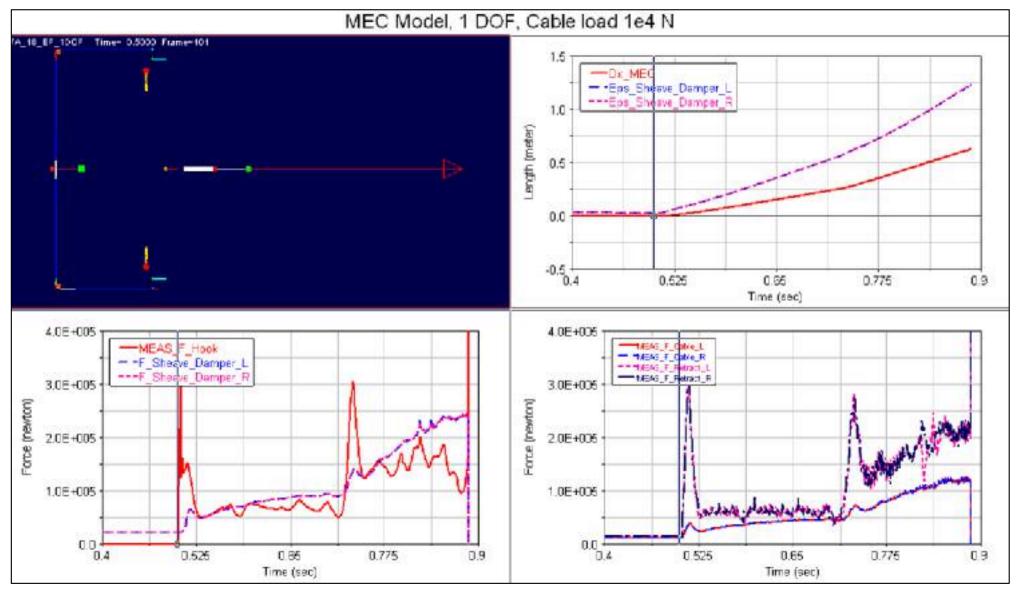


→ Model 3: Cross-deck cable dynamics slightly off



Model 4 (15 m cable): initial behaviour



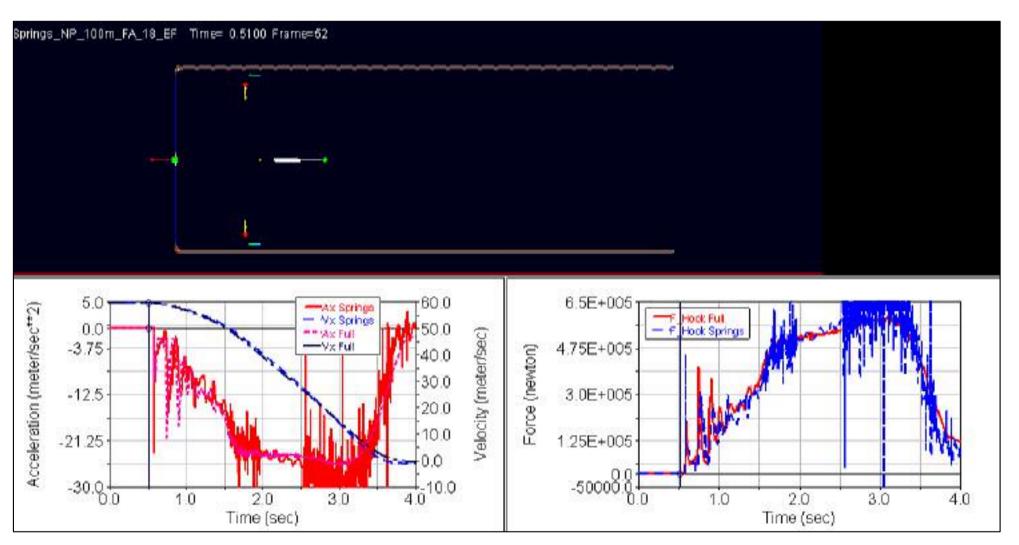


 \rightarrow Model 4: Cable kink wave dynamics seems realistic



Model 2 vs. model 4



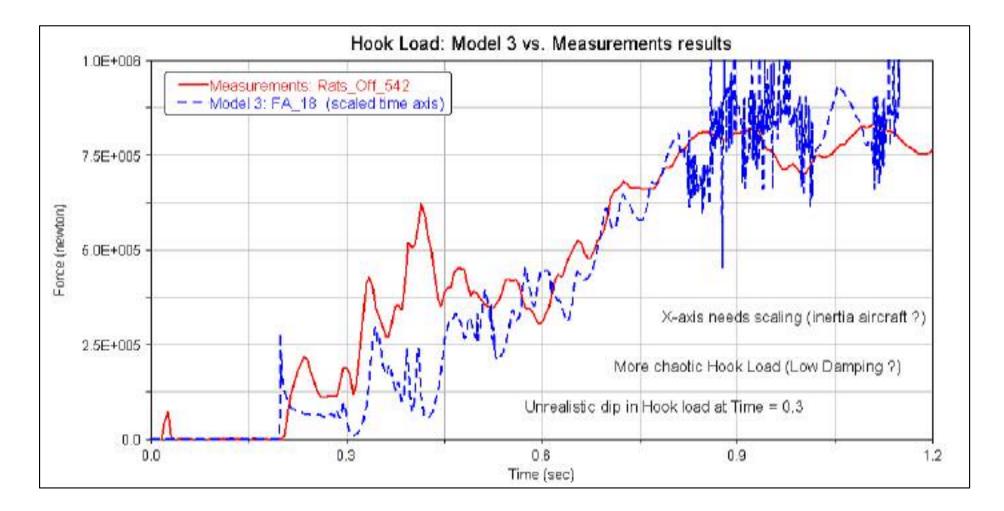


 \rightarrow Discrete cables give better damping properties





Model 3 (modified) vs. measurements

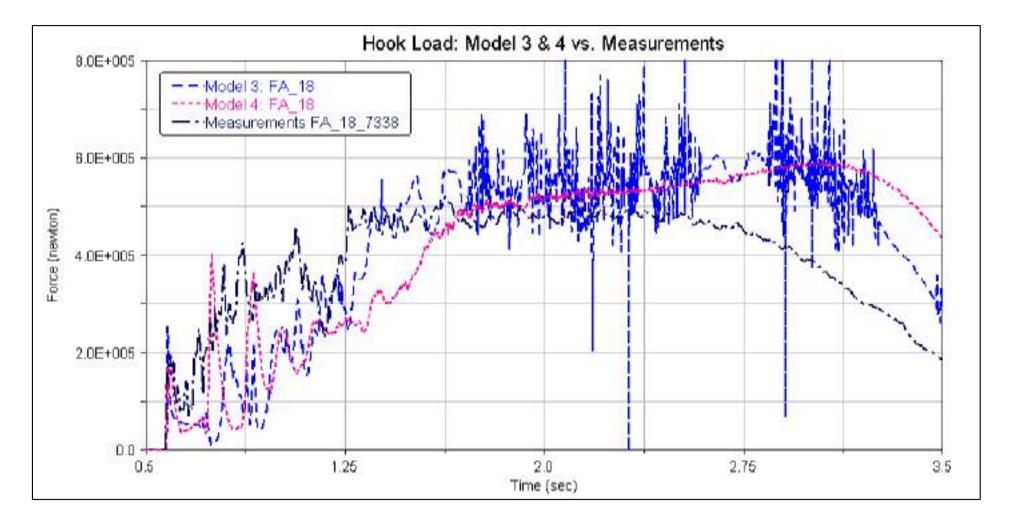


 \rightarrow Startup differences model 3 vs. measured explainable





Model 3 and 4 vs. measurements

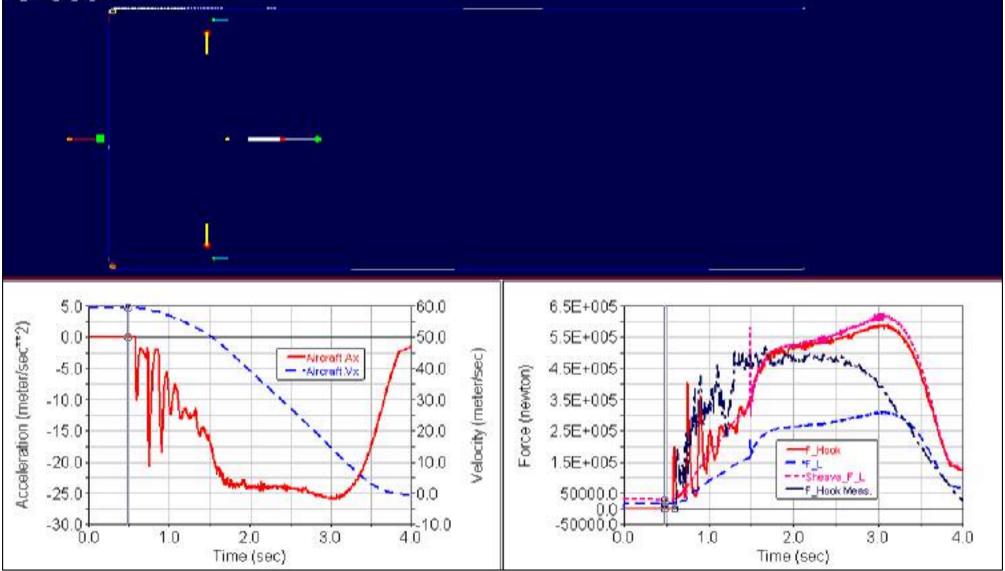


Overall differences model 3&4 vs. Measured tunable



Model 4 (100 m cable) vs. measurements





→ Model parameters need tuning



Conclusions



- 1. Model results:
 - Use of multiple models (both complex and simple) is efficient when doing a complex simulation project;
 - The models created appear to be able to describe the kink-wave dynamic phenomenon in a way usefull for design optimisations.
- 2. Using a *hybrid* approach: (axial+transversal cable models) the complete arrest gear dynamics can be simulated.
- 3. Sensitivity studies:
 - At current settings, the influence of axial and lateral cable parameters is small;
 - The position of the sheave damper (and modelling method) has a large effect on the hook load simulated;
 - Several other parameters have to be varied and extra effects need to be modelled to achieve proper model verification.





Future work to be done

- Cable models:
 - *Hybrid* cable models: Discrete + Spring-Based
 - Parameters for Spring-Based cables: inertia at Len(t) , lateral damping/stiffness
 - Cable-pulley contacts: CPU speed up (factor 10 ?)
- System effects to be implemented:
 - Sheave friction, cable friction
- Arrest gear model components to be defined:
 - Anchor dampers
 - MEC: piston + 18 cable parts
- Model verification on Measurements